

The contribution of Quasars to the Far Infrared Background

G. Risaliti^{1,2}, M. Elvis¹, R. Gilli^{2,3}

ABSTRACT

Recent observational results obtained with SCUBA, COBE and ISO have greatly improved our knowledge of the infrared and sub-mm background radiation. These limits become constraining given the realization that most AGNs are heavily obscured and must reradiate strongly in the IR/sub-mm. Here we predict the contribution of AGNs to the IR/sub-mm background, starting from measurements of the hard X-ray background. We show that an application of what we know of AGN Spectral Energy Distributions (SEDs) and the IR background requires that a significant fraction of the 10-150 μm background comes from AGNs. This conclusion can only be avoided if obscured AGNs are intrinsically brighter in the X-rays (with respect to the optical-UV) than unobscured AGNs, contrary to “unified schemes” for AGNs, or have a dust to gas ratio much lower (≤ 0.1) than Galactic. We show that these results are rather robust and not strongly dependent on the details of the modeling.

Subject headings: galaxies: active — X-rays: diffuse background — infrared: galaxies

1. Introduction

The total energy released by AGNs, as inferred from the X-ray background intensity at 30 keV, and using a reasonable bolometric correction, is a significant fraction of the total luminosity of the Universe (Fabian & Iwasawa 1999, hereafter FI99, Elvis, Risaliti & Zamorani 2001, hereafter ERZ01). ERZ01 estimate that the total luminosity emitted by AGNs cannot be lower than 6% of the total, and could well be 15-20%. This is a consequence of the large fraction, $\sim 80\%$, of AGNs that are heavily obscured. Heavy obscuration requires re-emission of the absorbed energy and suggests that the contribution of AGNs to the far

¹Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138

²Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125 Firenze, Italy

³Dept. of Physics and Astronomy, The Johns Hopkins University, Baltimore, MD 21218

infrared background (FIRB) could also be large. In this work we investigate the contribution of AGNs to the infrared background, using the latest observational data. Furthermore, the total luminosity emitted by AGNs can be compared with the mass density of supermassive black holes in order to investigate the average efficiency of accretion in converting mass into energy. This second important issue is discussed in the companion paper ERZ01.

The X-ray spectrum of a type 1 (broad lined) AGN in the 2-30 keV energy range is well described by a power law with photon index ~ 1.8 -2 (Nandra & Pounds 1994, Nandra et al. 1997). If the X-ray background is made by AGNs, then the only way to reproduce the observed XRB spectrum is by assuming a large number of heavily obscured AGNs as the main contributors to the XRB, as first suggested by Setti & Woltjer (1989). Recent synthesis models that were able to reproduce the XRB spectrum (Comastri et al. 1995, Gilli, Salvati & Hasinger 2001, hereafter G01) predict that only 10-20% of the XRB at 30 keV is due to type 1 AGNs, while 80%-90% of all AGNs are heavily obscured, type 2 objects. We can then use these synthesis models to predict the contribution of AGNs to the FIRB, using an average FIR SED instead of an X-ray SED.

To make an useful estimate would seem to require some knowledge of the FIR SED of obscured AGN. Two further uncertainties concern the evolution with redshift of obscured AGNs, which is still debated, and is probably different from that of unobscured AGNs (G01), and the column density distribution of these objects at high z . Finally, the spectral shape of the FIRB between 10 and 200 μm is unknown. However, we show in this paper that we can draw several important conclusions despite these uncertainties.

2. Measurements of the FIRB and Quasar Source Counts

Here we review the main observational constraints on the 10 μm -1 mm background.

850 μm : Deep *Chandra* and SCUBA observations of blank fields showed that the sources making the bulk of the XRB in the 2-10 keV band and those making the 850 μm background are unrelated (Severgnini et al. 2000, Fabian et al. 2000). As a consequence, AGNs are expected to contribute little ($< 10\%$) to the sub-mm background. We note however that the SCUBA sources could also be powered by completely Compton-thick AGNs. This would imply that the fraction of Compton-thick AGNs at high redshift would be much higher than in the local Universe. This scenario would strengthen our conclusions, as we will briefly discuss below.

140 μm , 240 μm : COBE/DIRBE measurements of the diffuse background at 140 μm and 240 μm (Lagache et al. 1999) give $\nu I_\nu(140 \mu\text{m}) = 15 \pm 6 \text{ nW sr}^{-1} \text{ m}^{-2}$, and $\nu I_\nu(240 \mu\text{m})$

$= 11 \pm 2 \text{ nW sr}^{-1} \text{ m}^{-2}$. This result is somewhat controversial, because of the difficulties in taking into account the foreground emission. Another group (Fixsen et al. 1998) finds results higher by 40%.

90 μm : There is no direct measurement of the background at this wavelength. The best data at 90 μm are the recent ISOPHOT source counts (Efsthathiou et al. 2000). However, at the minimum flux detectable at this wavelength (150 mJy) the integrated intensity, Ψ_{90} , derived from the current logN-logS, is not constraining, being only a small fraction of the background ($\sim 5\%$).

60 μm : An analysis of COBE/DIRBE data, performed by Finkbeiner et al. (2000) gives a 60 μm background emission of $28 \pm 9 \text{ nW m}^{-2} \text{ sr}^{-1}$. However, this measurement is not compatible with the upper limit imposed from the TeV emission of blazars (Renault et al. 2000). Therefore, there is either another unknown foreground source to be removed, or the limits estimated from the TeV emission of blazars are underestimated, due to the poor knowledge of the quasar SED in the TeV range. However, we can regard this value as an upper limit.

15 μm : The ISOCAM survey at 15 μm provided a logN-logS with $S > 100 \mu\text{Jy}$ (Elbaz et al. 1999) and, since in this case the logN-logS curve flattens below the Euclidean value at faint fluxes, is likely to have resolved a significant fraction of the 15 μm background. If we extrapolate the faint logN-logS to zero flux and calculate the contribution to the background of the extrapolated part, we find that it is only a few percent of the contribution from the resolved sources.

1-50 μm : Observations of blazars in the TeV range give upper limits on the infrared background from $\sim 1 \mu\text{m}$ to $\sim 50 - 60 \mu\text{m}$, deduced from the lack of a cutoff in their TeV spectra which would be produced by Compton scattering of TeV photons off the IR background (Stanev & Franceschini 1998).

Putting together these constraints, in Fig. 1 we plot the observational limits discussed above, and the arbitrary analytic fit of Fixsen et al. 1998 (thick line) for the FIRB SED. The plotted quantity, Ψ , is defined as $E \times f(E)$, where E is the energy and $f(E)$ the monochromatic flux density. Integrating gives $\Psi_{\text{IRB}} = 26 \text{ nW m}^{-2} \text{ sr}^{-1}$. For comparison, the $\Psi_{\text{IR,AGN}}$ derived for the absorbed AGN radiation by ERZ01 is $\Psi_{\text{IR,AGN}} = (3.6-6.5) \text{ nW m}^{-2} \text{ sr}^{-1}$.

3. Constraints on X-ray obscured AGNs from FIR measurements

Here we compare the observational constraints on the FIRB summarized above with a quantitative synthesis model

obtained from the code of G01, that reproduces both the XRB spectrum and the counts in the hard X-ray surveys of BeppoSAX (Giommi et al. 2000) and ASCA (Akiyama et al. 1999). In this model there are two X-ray SEDs used as input: one is the average SED of unobscured AGNs, the other is obtained as a weighted average of the SEDs of obscured AGNs with 5 different value of absorbing column density (for further details, we refer to G01). The XRB spectrum is obtained integrating these SEDs using the X-ray luminosity functions of Miyaji et al. (2000), leaving only the ratio between obscured and unobscured AGNs as a free parameter. The best agreement with the XRB spectrum and source counts is obtained assuming an increase of the number ratio, R , between type 2 and type 1 AGNs from the local $R \simeq 4$, to $R \simeq 10$ at $z \simeq 1.3$.

We used this model, only substituting FIR SEDs in place of the X-ray SEDs. For type 1 AGNs we assumed the SED of Elvis et al. (1994) (the normalization was re-scaled from the 2 keV value using $\alpha_{OX} = 1.55$ and $\alpha_{OX} = 1.68$ ⁴). For type 2 AGNs we assumed a FIR SED with several shapes, in order to be consistent with the observational data and to investigate how the final results of our analysis depend on the details of the SED. We discuss these issues below. However we note that the integrated intensity obtained with this model is (obviously) independent of the shape of the SEDs. We also note that the details of the redshift distribution of absorbed sources do not affect much our results, since the ratio between the total absorbed and transmitted flux is fixed by the slope of the XRB between 2 keV and 30 keV (ERZ01). The baseline value we obtained is: $\Psi_{base} = 3.8 (C_{BOL}/C_{PG}) \text{ nW sr}^{-1} \text{ m}^{-2}$ where C_{BOL} is the 2 keV-to-bolometric correction and C_{PG} is the bolometric correction for local ($z < 0.4$) PG quasars (i.e. assuming $\alpha_{OX} = 1.55$). C_{PG} can be regarded as a lower limit for the real bolometric correction (ERZ01). Assuming a redshift evolution of α_{OX} to $\alpha_{OX} = 1.68$ at $z=2$ as estimated by Yuan et al. (1998), gives $C_{BOL} \sim 2.2 C_{PG}$. The value we obtain is ~ 2 -4 times higher than the value obtained by FI99 ($\Psi_{FI99} = 2 \text{ nW sr}^{-1} \text{ m}^{-2}$). The fraction of the total infrared background made by AGN is $\Psi_{base}/\Psi_{IRB} \sim 15\% \times (C_{BOL}/C_{PG})$

We used several FIR SEDs for absorbed AGNs. We first assumed a simple, single temperature, blackbody in the 10-1000 μm band. The results are plotted in Fig. 1 for three different temperatures. The normalizations are determined only by the X-ray data and the

⁴ α_{OX} is defined as the slope of a power law connecting the flux density at 2500Å with the flux density at 2 keV, as explained below and in ERZ01

bolometric correction discussed above, not by the FIR data. The allowed temperature range is constrained by the SCUBA data of Severgnini et al. (2000): average temperatures lower than 120 K overproduce the AGN contribution to the FIRB at 850 μm . We repeated the calculation at 120 K allowing for redshift evolution to lower X-ray loudness (i.e. $\alpha_{OX}=1.68$ at $z=2$, ERZ01, Yuan et al. 1998). The result is to shift the curve higher (the upper bound of the shaded region in Fig. 1). The true bolometric correction then lies within the shaded region.

A more realistic, multi-temperature, blackbody SED does not change this result significantly. To investigate the effect of multi-temperature FIR SEDs we held the lowest temperature at 80 K and added two components with temperatures of 120 K and 160 K. The result of the model is a curve indistinguishable from that obtained with a single temperature SED of the appropriate temperature (~ 110 K). This constancy is due to the dominance of redshift dilution, as explained below.

Strong line emission is a major ISM coolant (Neufeld et al. 1995, Melnick et al. 2000). Given the poor sampling of the FIRB, perhaps such sharp line features could be present and so void the limits derived from broad continuum models. To test this possibility we assumed a blackbody SED with $T=120$ K, plus a narrow emission line at 15 μm that accounts for \sim half of the total intensity. This case (which is not intended to refer to a physically realistic model) is also plotted in Fig. 1 (dashed line) and shows the strong effect of the dilution in redshift: the strong, narrow feature is broadened over the 15-90 μm range (the cut-off at 90 μm is due to the model cut-off at $z=5$), and the shape of the final curve is not markedly different from those obtained with thermal SEDs. Since the feature we assumed is an extreme case, we conclude that the details of the average SED of obscured AGNs do not affect our results, only the mean temperature being important. This “redshift dilution” is analogous to the dilution of the iron $K\alpha$ line in the spectrum of the hard X-ray background (Gilli et al. 1999). Given the independence of the main results from the details of the SED, in the following we discuss the consequences of our results using only thermal SEDs, without losing generality. The temperatures we use can be regarded as “effective” temperatures, T_{eff} , of the actual, unknown SED.

We note that our choice of wavelength range is rather conservative in that it assumes that the dust is optically thin at all infrared wavelengths. Indeed, if we assume a standard dust-to-gas ratio, we expect that in objects with $N_H >$ a few 10^{22} cm^{-2} (which constitute more than half of the local AGN population, Risaliti et al. 1999), the emission in the 10-20 μm is absorbed and reradiated at longer wavelengths. For objects with $N_H >$ a few 10^{23} cm^{-2} absorption is still significant at 25 μm . If we take this into account, we must narrow the range of the re-emission, thus increasing the specific intensity at wavelengths longer than

30 μm . We will return to this problem in the next section.

Finally, another possible increase to the AGN contribution to FIRB could come from a population of Compton-thick AGN, which make no contribution to the X-ray background, but re-radiate all the intrinsic emission in the far infrared. In our model we assume that the fraction of such objects is 20% of absorbed AGNs, which is a lower limit for nearby low-luminosity Seyfert 2s (Risaliti et al. 1999). Assuming, for example, a fraction of 50%, the contribution of AGNs to the 100 μm background would be probably higher than 50% (depending on the SED of these objects).

4. Discussion

Our simple argument shows that despite the lack of knowledge of the background radiation over quite wide wavelength intervals in the far infrared, we can use the observational data on the AGN SED and synthesis models for the X-ray background to make interesting predictions on the AGNs contribution to the FIRB.

Several works have recently computed the AGN contribution to the FIR/sub-mm background starting from XRB synthesis models (Almaini et al. 1999). These papers focus mainly on the prediction of the contribution of AGNs to the SCUBA counts. Trentham & Blain (2001) already pointed out that the re-radiation of the primary emission of AGNs cannot be due to cold (~ 40 K) dust, since this is not consistent with the SCUBA source identifications. Here we have used a more robust argument, using an improved, higher, AGN bolometric correction, and deriving the results in a general and only weakly model-dependent way.

From an analysis of Fig. 1 it is clear that (a) the lack of correlation between the X-ray and 850 μm background; and (b) the ISOCAM source counts at 15 μm , are enough to give new interesting constraints on the spectrum of the FIRB due to AGNs. If all our main assumptions are correct, the only way to obtain agreement with all the observational data is through a thermal SED with $120 \text{ K} < T_{eff} < 180 \text{ K}$.

We note that the temperature range can be shifted towards lower values if we assume a different Spectral Energy Distribution. In several cases the spectrum of the re-radiated emission is modeled with a modified thermal function, $f(E) \propto E^k \times B(E)$, with $k > 0$. We repeated all our calculations assuming $k=1$. The results are basically unchanged, with the exception of the temperature interval, which goes from 80 K to 120 K. For comparison, nearby ULIRGs which host an AGN have an effective temperature between 50 and 80 K, when a SED with $k \sim 1$ is assumed. We note however that it is at present extremely difficult

to disentangle the starburst and AGN components even in the most studied ULIRGs. It is probable that in many sources hosting an AGN, a starburst contribution is also important. This component can lower the measured effective temperature.

The contribution of AGNs to the FIRB strongly affects constraints on galaxy evolution. In background synthesis models in which the stellar component is dominant, for example, a “passive galaxy evolution” model cannot reproduce the whole FIRB, unless the stellar initial mass function is strongly different from the Salpeter IMF and is cut at low masses (Franceschini 2000). The significant contribution of at least $\sim 15\%$ to the FIRB from AGNs indicated by our analysis alleviates this problem, since the total energy emitted by stars and reprocessed in the FIR will be significantly lower by a factor at least 1.7.

Alternatively fast galaxy evolution with redshift reproduces the FIR counts in deep surveys with no contribution of AGNs (Chary & Elbaz 2001). In this case, as emphasized by these authors, a contribution of AGNs to the FIRB higher than $\sim 15\%$, as we derive, would imply a slower evolution of the galaxy luminosity functions with redshift. Assuming $T_{eff} \sim 120K$ we predict a maximum of the AGN contribution from 20% to 40% at 60 μm . If the effective temperature, T_{eff} , is higher, the wavelength at which we expect the maximum contribution is lower. In these cases the AGN contribution can easily be higher than 50%, and could even reach 100%. Again, we remind that if we take into account the absorption at 10-30 μm in the most heavily absorbed objects, we predict higher emission at 60-100 μm , and a lower one at $\lambda < 30 \mu m$.

Our argument is not 100% watertight: (a) the dust content of the AGNs making the X-ray background could be significantly lower than currently assumed, or (b) the dust composition could be different.

(a) Several recent studies suggest low dust-to-gas ratio: Granato et al. (1997) propose a low dust-to-gas ratio in X-ray obscured AGNs, from the comparison of the infrared data with their models. Spectroscopically selected quasars suggest the existence of a significant population of AGNs with a low dust-to-gas ratio (Risaliti et al. 2001). As a consequence, the contribution of AGNs to the FIRB estimated in these cases could be negligible: if we assume that the re-radiation band extends down to wavelengths of $\sim 1 \mu m$, the FIR emission due to AGNs drop by $\sim 30\%$. The drop could be much lower if a significant fraction of the optical-UV primary emission is not reprocessed in the IR. This is for example the case of Broad Absorption Line Quasars, which are heavily absorbed by gas in the X-rays (Mathur, Elvis & Singh 1995, Brandt et al. 2000) but little reddened by dust.

(b) If dust grains in AGNs are much larger, on average, than the standard Galactic composition then the absorption curve of dust would be flatter, and the absorption efficiency significantly lower, than for dust with Galactic size distribution (Laor & Draine 1993). A

recent study of the continuum and line absorption in nearby intermediate AGNs suggest that this could be the correct scenario for a significant fraction of AGNs (Maiolino et al. 2001a, 2001b).

Finally, we note that the obscured AGNs that make the X-ray background may have intrinsically higher X-ray to optical ratio. As a consequence, the bolometric correction we adopted would be overestimated and the total intensity reradiated in the far infrared would be correspondingly lower. This scenario is an alternative to unification models, and cannot be ruled out, given our lack of knowledge on the so-called “quasar 2s”.

In the near future several new observational opportunities are expected, which will tightly constrain our model, revealing the properties and the amount of dust of the AGN contributing to the FIRB: (a) the new X-ray satellites Chandra and XMM-Newton are already providing X-ray spectra of high redshift AGNs. From the comparison between the X-ray and infrared properties of these objects we will be able to have a direct measurement of the contribution of high redshift AGNs to the FIRB. Complementary information, at lower redshift will come from the infrared characterization of the sources found in the deep ASCA and BeppoSAX surveys, like HELLAS (Fiore et al. 1999). (b) Sensitive infrared surveys and identifications, most notably with SIRTf, will test the predictions in Figure 2. More precisely, SIRTf will allow us to measure the SEDs of the hard X-ray background sources, thus giving a direct test for the model proposed here. It will also allow us to study via follow-up of $70\ \mu\text{m}$ sources, other contributors to the FIRB (like, for example, Compton thick dusty AGNs).

Our model has two main degrees of freedom, as discussed above: the effective temperature of the assumed SED, and the total amount of radiation reprocessed by dust. The optical identification of the sources found in the ISOCAM survey at $15\ \mu\text{m}$ will give a first useful constraint. The AGN contribution to the FIRB around $\sim 60\ \mu\text{m}$ is quite stable to changes in T_{eff} . SIRTf will resolve the bulk of the background at $70\ \mu\text{m}$, reaching a flux of $\sim 100\ \mu\text{Jy}$ for point sources, with accurate positions that will enable ready identifications. SIRTf will also resolve a significant fraction of the $160\ \mu\text{m}$ (flux limit $\sim 1\ \text{mJy}$). These data will tightly constrain our model: a high AGN contribution at $15\ \mu\text{m}$ ($>50\%$) would constrain the SED effective temperature to around 160-180 K. This would imply that the dust responsible to the reprocessing of the optical and UV radiation is much warmer than usually assumed, and that the total amount of dust in AGNs has to be low, with respect to the gas column densities measured in the X-rays. Conversely, a low AGN contribution at $15\ \mu\text{m}$ would imply that the dust is on average colder or that the UV and optical primary emission is not almost entirely reprocessed by dust (i.e. there are more dust-free lines of sight than assumed from the X-rays). The $70\ \mu\text{m}$ measurement would discriminate between

these two scenarios. Finally, if the AGN contribution to the 70 μm background is dominant, contrary to our predictions, this would imply that the fraction of completely Compton-thick AGN is much higher than we assumed.

Summarizing, in this work we have combined all the available data on AGN SEDs and X-ray background models on one side, and on the FIRB on the other side. We have found, with an approach that is only weakly model-dependent, that the contribution of AGNs to the infrared background is not negligible, and could be dominant in the 15-50 μm band (if, for example, the fraction of Compton thick AGNs is higher than our conservative estimate of 20%). This has large consequences for models of galaxy evolution. The only possible alternatives are that AGNs have quite different SEDs than usually assumed, or that the dust content or composition in absorbed AGNs is quite different from Galactic. These quantities will be tested soon with ISO and SIRTf.

We are grateful to G. Zamorani for fruitful discussions. This work was supported in part by NASA grant NAG5-4808.

REFERENCES

- [1]Akiyama, M., et al. 2000, ApJ, 532, 700
- [2]Almaini, O., Lawrence, A., & Boyle, B.J., 1999, MNRAS, 305, L59
- [3]Brandt, W.N., Laor, A., & Wills, B.J. 2000, ApJ, 528, 637
- [4]Chary, R., & Elbaz, D. 2001, ApJ, 556, 562
- [5]Comastri, A., Setti, G., Hasinger, G., & Zamorani, G., 1995, A&A, 296, 1
- [6]Elbaz, D., et al. 1999, A&A, 351, 37
- [7]Efstathiou, A., et al. 2000, MNRAS, 319, 1169
- [8]Elvis, M., et al., 1994, ApJS, 95, 1
- [9]Elvis, M., Risaliti, G., & Zamorani, G. 2001, ApJL, in press
- [11]Fabian, A.C., & Iwasawa, K., 1999, MNRAS 303, L34
- [11]Fabian, A.C., et al. 2000, MNRAS, 315, L8
- [12]Finkbeiner, D.P., Davis, M., & Schlegel, D.J., 2000, ApJ, 544, 81

- [13] Fiore, F., La Franca, F., Giommi, P., Elvis, M., Matt, G., Comastri, A., Molendi, S., & Gioia, I. 1999, MNRAS, 307, L55
- [14] Fixsen, D. J., Dwek, E., Mather, J. C., Bennet, C. L., & Shafer, R. A. 1998, ApJ, 508, 123
- [15] Franceschini, A., et al. 2000, ApJ, in press (astro-ph 0108292)
- [16] Gilli, R., Comastri, A., Brunetti, G., & Setti, G., 1999, NewA, 4, 45
- [17] Gilli, R., Savati, M., & Hasinger, G. 2001, A&A, 366, 407
- [18] Giommi, P., Perri, M., & Fiore, F. 2001, A&A, 362, 799
- [19] Granato G. L., Danese, L., & Franceschini, A. 1997, ApJ, 486, 147
- [20] Lagache, G., Abergel, A., Boulanger, F., Desert, F.X., & Puget, L.J., 1999, A&A 344, L322
- [21] Laor, A., & Draine, B. 1993, ApJ, 402, 441
- [22] Laor, A., Fiore, F., Elvis, M., Wilkes, B.J. & McDowell, J.C. 1997, ApJ, 477, 93
- [23] Maiolino, R., Marconi, A., Salvati, M., Risaliti, G., Severgnini, P., Oliva, E., La Franca, F., & Vanzi, L. 2001a, A&A, 365, 28
- [24] Maiolino, R., Marconi, A., & Oliva, E. 2001, A&A, 365, 37
- [25] Mathur, S., Elvis, M., & Singh, K.P. 1995, ApJ, 455, 9
- [27] Melnick, G.J., et al., 2000, ApJ, 539, L129
- [27] Miyaji, T., Hasinger, G., Schmidt, M. 2000, A&A, 353, 25
- [28] Nandra, K., & Pounds, K. A. 1994, MNRAS, 268, 405
- [29] Nandra, K., George, I. M., Mushotzky, R. F., Turner, T. J., & Yaqoob, T. 1997, ApJ, 476, 70
- [30] Neufeld, D.A., Lepp, S., & Melnick, G.J. 1995, ApJS, 100, 132
- [31] Peterson, B.M. 1997, “An introduction to active galactic nuclei”, Cambridge University Press.
- [32] Renault, C., Barrau, A., Lagache, & G., Puget, J.-L., 2000, A&A, submitted (astro-ph/0012094)

- [33]Risaliti, G., Maiolino, R., & Salvati, M., 1999, ApJ, 522, 157
- [34]Risaliti, G., Marconi, A., Maiolino, R., Salvati, M., & Severgnini, P. 2001, A&A, 371, 37
- [36]Setti, G., & Woltjer, L. 1989, A&A, 224, L21
- [36]Severgnini, P., et al. 2000, A&A, 360, 457
- [37]Stanev, T., & Franceschini, A. 1998, ApJ 494, L159
- [38]Trentham, N., & Blain, A.W., 2001, MNRAS, 323, 547
- [39]Yuan, W., Brinkmann, W., Siebert, J., & Voges, W. 1998, A&A 330, 108

Fig. 1.— Thick continuous line: FIRB, obtained using the analytic fit of Fixsen et al. (1998) in the 1000-120 μm range, and connecting the 120 μm and the 15 μm points with a powerlaw. The points at 140 and 240 μm are from COBE (Lagache et al. 1999), the point at 15 μm is our estimation based on ISOCAM logN-logS (Elbaz et al. 1999); the upper limit at 850 μm refers to the AGNs contribution to the background, and is estimated on the basis of the SCUBA results in Severgnini et al. (2000). The continuous line on the top right of the diagram is an upper limit obtained from TeV spectra of Blazars (Franceschini 2000). The three dotted lines are the results of our models, for 3 different dust temperatures, assuming the X-ray to bolometric correction of local quasars. The shaded region has its lower bound the 120 K SED and uses the bolometric correction of local quasars, while the upper bound is given by the same SED, but assuming the bolometric correction corresponding to an observed $\alpha_{OX}=1.68$. The dashed line is obtained assuming a dust temperature of $T=120$ K and a narrow emission line at 15 μm that accounts for half of the total intensity. The thin continuous line is obtained assuming a more complex SED, given by the sum of three thermal SEDs with three different temperatures (160 K, 120 K, 80 K).

